ASSESSMENT OF STEEL FLOOR PLATES INSTALLED ON DIFFUSER GRATINGS TO FACILITATE PASSAGE OF ADULT PACIFIC LAMPREY THROUGH FISH LADDERS

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Introduction

Pacific lamprey (*Lampetra tridentata*) populations in the Columbia Basin are in decline (Jackson, et al., 1996). The Oregon Department of Fish and Wildlife mentioned Pacific lamprey as a species at risk of being listed as threatened or endangered in 1993. The U.S. Fish and Wildlife Service designated the Pacific lamprey as a species of concern in 1994. The 1994 Fish and Wildlife Program of the Northwest Power Planning Council remarked on the decline of Pacific lamprey and requested a status report to identify research needs. The Columbia Basin Pacific Lamprey Technical Workgroup was formed in 1996 to identify research needs and to coordinate ongoing and future studies designed to meet these needs.

Recent studies of Pacific lamprey passage at dams indicate that fish ladder junction pools and pools with diffuser floor gratings are problem areas where some lamprey turn around and go back downstream (Ocker, et al., 2001). Fishway designs and improvements at Pacific Northwest dams have almost always focused on salmon passage. Only recently have modifications been suggested for improving lamprey passage. This report evaluates the effectiveness of one such modification.

Objectives

The objectives as stated in the study proposal of 31 October 2001 were:

1. Determine if lamprey passage through diffuser pools is improved by the use of floor gratings modified with steel plates between weir orifices.
2. Determine the feasibility and application of using an acoustic camera to observe adult lamprey behavior and passage in areas with diffuser gratings and solid concrete. Determine whether lamprey use steel floor plates at the junction pool and between weirs at the Washington shore ladder.

In pursuit of objective 2, an acoustic camera (DIDSON) was deployed at the junction pool by personnel under contract to the Pacific Northwest National Laboratory. Good images were obtained of the floor of the pool; the steel plate was clearly differentiated from the surrounding concrete. Fish, including shad, sturgeon, and salmonids, were readily identified. No lamprey were seen on or near the steel plate or anywhere else in the pool. Since lamprey were almost certainly present during at least part of the several hours of observation, it is likely that lamprey are largely transparent to the acoustic camera. Lamprey have no air bladder, no scales, and no hard skeleton. These, in large part, are what make fish visible by acoustic means. No further reference will be made to objective 2 in this report.

Methods

The study site for objective 1 included the three pools at the lower part of the Washington shore ladder between weirs 27 and 30. The pools between weirs 27 and 28 and between weirs 29 and 30 are diffuser pools; the entire floor consists of diffuser gratings (Fig. 1). The floor of the pool between weirs 28 and 29 is concrete. Steel plates were installed in the two diffuser pools as indicated in the figure. The plates were 18 inches wide (same width as the orifices) and bridged the entire distance between weirs. Only one pair of orifices was bridged in each diffuser pool, the east orifices in the lower pool (27E to 28E) and the west orifices in the upper pool (29W to 30W). The other pair of orifices in each of the diffuser pools was intended as a control. The alternation between east and west was intended to lessen the effect of any east-west bias in lamprey passage.

Each of the eight orifices (both orifices on each of the four weirs) was monitored with an underwater video camera. Aluminum guides were bolted to the side walls approximately two feet upstream of each orifice. The guides extended from the top of the wall (55-deck) to the floor of the ladder. The cameras were attached to mounts which slid down the guides. The cameras with their attached cables were lowered to a position just above the floor at the level of the orifices. Each camera was aimed downstream and slightly away from the wall in order to view the orifice and that part of the floor of the fish ladder immediately upstream and downstream of the orifice. The entire orifice was visible and covered approximately 50% of the field of view. Adult lamprey in the field of view always produced reasonably large images in this arrangement. The output from each camera was recorded on a separate video tape recorder. A date and time marker was recorded on each video frame. The clocks on all eight recorders were synchronized.

Video observation was conducted on twelve days between 18 June 02 and 30 July 02 (Table 1). Simultaneous recordings were made for all eight cameras for six hours each day of the study between the hours 1200 and 1800. If there was an equipment malfunction for all or part of the six hours for any camera, the counts for that camera and the other camera on the same weir for the entire day were not used in the analysis and are recorded as missing in the table.

The first step in processing the data was to play back the tapes and tally up-counts and down-counts for lamprey passing through the orifices. Four members of the FFU staff viewed the tapes. As a rule one person would do the entire set of tapes for one date. This insured that observers and sites were well mixed and, in particular, that the same observer looked at both tapes for the two orifices on the same weir for the same date. The data were recorded at 30 frames per second and played back at normal speed. For the analysis, pair-wise comparisons were made between the total daily up-counts for the two orifices on the same weir. Specifically, we wanted to determine if a greater proportion of lamprey used the orifice with a steel plate adjacent compared to the orifice with diffuser grating adjacent. Analogous comparisons were made for down-counts.

Results

In analyzing the results for objective 1, the following assumptions were made:

1. If the steel plates were beneficial to lamprey passage, the presence of a steel plate on the downstream side of an orifice should result in increase up-counts at that orifice relative to the other orifice on the same weir. That is, up-counts at 28E on a particular date should be higher than the up-counts at 28W for the same date, and, likewise, up-counts at 30W should be higher than the corresponding up-counts at 30E (Fig. 2).
2. If the steel plates were beneficial to lamprey passage, the presence of a steel plate on the upstream side of an orifice should result in a decrease in down-counts at that orifice relative to the other orifice on the same weir. That is, down-counts at 27E should be lower than the corresponding down-counts at 27W, and down-counts at 29W should be lower than the corresponding down-counts at 29E.
3. If there was an eastside vs. westside bias in lamprey passage, this might be detected by comparing up-counts at weir 27 (27E vs. 27W) and possibly at weir 29 (29E vs. 29W). The pools downstream of these weirs have neither diffuser gratings nor steel plates. This assumption is probably a better one at weir 27; the interpretation of counts at weir 29 is confounded because the lamprey have presumably encountered the diffuser grating and/or steel plate in the pool below weir 28.

The up-counts and down-counts for all of the videotaped observations are given in Table 1. [Anomalous counts at weir 29 on 6.18.02] The analysis of up-counts at weirs 28 and 30 is given in Table 2. At weir 28, 250 lamprey were observed passing up through the orifices during 54 hours of observation. 58% percent used the orifice with the steel plate downstream, 42% used the orifice without the plate. At weir 30, 340 lamprey were observed passing up through the orifices during 66 hours of observation. 60% used the orifice with the plate, 40% used the orifice without the plate. The significance of these results was tested using the sign test for paired observations. The sign of the difference (plate minus no plate) is tabulated in the rightmost column. For weir 28 there are 5 plus out of 8 total (a zero difference is discarded from the analysis). For a two-tailed sign test, this is not significant at alpha = .05. For weir 30, there are 10 plus out of 11 total. This is significant at alpha = .05. For weirs 28 and 30 combined, there are 15 plus out of 19 total. This is also significant at alpha = .05.

The analysis of down-counts at weirs 27 and 29 is given in Table 3. At weir 27, 15 lamprey were observed dropping down through the orifices during 54 hours of observation. 27% dropped down through the orifice with a plate upstream, 73% through the orifice without a plate. At weir 29, 32 lamprey were observed dropping down during 60 hours of observation. The rightmost column is again the sign of plate minus no plate. For weir 27 there are 5 minus out of 5 total. This result is not significant (alpha = .05). For weir 29 there are 5 minus out of 6 total. This also is not significant (alpha = .05). For weirs 27 and 29 combined, there are 10 minus out of 11 total. This is significant at alpha = .05.

To test for a possible east-west bias, up-counts for weirs 27 and 29 are analyzed in Table 4. At weir 27, 231 lamprey were observed passing up through the orifices during 54 hours of observation. 49% used 27E, 51% used 27W. The sign test for east minus west results in 4 plus out of 8 total. This is a 50-50 split between plus and minus, and, obviously, there is no significant difference. (In a sign test, a 50-50 split indicates no difference at all.) At weir 29, 357 lamprey were observed passing up during 60 hours of observation. 56% used 29E, 44% used 29W. The sign test gave 5 plus out of 10 total, another 50-50 split. And, of course, weirs 27 and 29 combine to give a 50-50 split, 9 plus out of 18 total.

Discussion

The results indicate that steel plates covering part of the diffuser gratings adjacent to the orifices, both above and below, may help lamprey pass through those orifices. Lamprey migrate upstream (at least in the fish ladders) by alternating short bursts of swimming with rest periods during which they attach to the substrate with their suctorial mouths. A steel plate downstream of an orifice could allow a lamprey to position itself favorably and rest, before attempting to swim through. A steel plate upstream of the orifice could give a lamprey something to attach to after swimming through, making it less likely to fall back, and allowing it to rest before moving on. Lamprey cannot attach to the diffuser gratings. For the two weirs which had a steel plate downstream of one orifice and uncovered diffuser grating downstream of the other, 59% of the observed upstream passage was at the orifice with the plate. The sign test for the two weirs combined indicate that this difference is not due to chance alone. It is difficult to judge whether this represents a meaningful aid to lamprey passage since we do not know what proportion of the total weir passage was through the orifices. In the section of the Washington shore fish ladder observed in this study, lamprey can move from one pool to another through the overflow notches at the crest of the weirs as well as through the submerged orifices. (They may also be able to pass over the top of the weirs or on the side walls above the weirs by coming out of the water.) Fewer lamprey fell back through orifices with a steel plate above compared to orifices with uncovered diffuser grating above. The sign test for the two weirs combined indicate that the difference is probably not due to chance alone. Too few lamprey were observed falling back to say anything about the magnitude of the difference. Even though up-counts at orifices with steel plates were higher, it can not be assumed that lamprey used the steel plates to pass from one weir to the next using the steel plate as a kind of bridge over the gratings. This may be so, but we obtained no direct evidence, either for or against, during this study. Lamprey can use the side walls of the fish ladders as well as the floor. It is not known which substrate is preferred. Presumably, in those pools with diffuser gratings covering the entire floor and no steel plates, they must use the side walls.

It was often difficult to see the lamprey when viewing the videotapes. There were three readily apparent causes for this difficulty. First, the water was turbid, so that the image of the lamprey was of low contrast against the background, the floor of the fish ladder. Second, the water in the pools is full of air bubbles. A few of the larger bubbles near the camera lens could momentarily completely obscure the entire field of view. This happened often. A means to keep the air bubbles away from near the lens (a few inches) would be a significant improvement. Finally, the lighting, which came from the sun and sky, often varied drastically over the course of the six hours of taping each day, especially on sunny days. Much of the time there was extreme contrast of light and shade in the field of view. If the orifice was in the shady part of the field, it was quite dark. A means to diffuse the light would be another improvement. Despite these difficulties, it is unlikely that many lamprey moving up through the orifices entirely missed detection. Typically a lamprey was in the field of view for several minutes. Even under the worst viewing conditions, it was detected. The same may not be true for fallback.

Three successive weirs were observed for this study. It would have been better if there had been some separation between them. Passage at a weir is probably not independent of passage at the weirs downstream, especially the next weir downstream. On the other hand, too much separation would defeat the value of observing multiple weirs in order to have them function as mutual controls.

Steel plates in diffuser pools may be beneficial to lamprey. How to use them to get the most benefit with the fewest adverse side effects, and whether the benefit would be truly meaningful, is still uncertain. Perhaps the best next step, before this approach is pursued, is to learn more about how lamprey move up a fish ladder from one weir to the next, with or without diffuser gratings in the pool.

Lamprey Orifice Passage Based on Video Observation

Up Counts

Date	27E	27W	28E	28W	29E	29W	30E	30W
6.18.02	12	23	3	1	16	158	26	32
7.03.02	M	M	M	M	7	11	9	19
7.04.02	2	1	10	0	14	2	2	12
7.09.02	2	8	M	M	24	8	3	6
7.10.02	25	21	17	24	45	12	15	27
7.15.02	M	M	8	9	M	M	7	11
7.16.02	30	18	37	25	35	32	12	14
7.22.02	M	M	M	M	16	25	M	M
7.23.02	21	30	27	27	36	41	28	47
7.24.02	19	12	34	18	21	23	33	26
7.29.02	2	5	9	0	3	1	2	7
7.30.02	0	0	0	1	0	1	0	2

Down Counts

Date	27E	27W	28E	28W	29E	29W	30E	30W
6.18.02	0	1	0	1	6	28	3	14
7.03.02	M	M	M	M	1	0	0	0
7.04.02	0	0	5	0	4	0	0	1
7.09.02	0	2	M	M	8	0	0	11
7.10.02	2	4	3	4	14	0	1	18
7.15.02	M	M	0	1	M	M	0	2
7.16.02	0	1	0	0	0	0	1	2
7.22.02	M	M	M	M	0	0	M	M
7.23.02	2	3	2	1	0	4	0	6
7.24.02	0	0	0	0	0	0	0	0
7.29.02	0	0	4	0	1	0	0	4
7.30.02	0	0	0	0	0	0	0	0

M = data missing
All entries are based on 6 hours of observation of videotape for that date and orifice.

Up Counts at Weirs 28 and 30 with a Steel Plate (Plate) Downstream of One Orifice and Diffuser Gratings (No plate) Downstream of the Other Orifice

	28E	28W			
Date	**Plate**	**No Plate**	**Total**	**Diff.**	**Sign**
6.18.02	3	1	4	2	+
7.03.02	M	M	M	M	M
7.04.02	10	0	10	10	+
7.09.02	M	M	M	M	M
7.10.02	17	24	41	-7	-
7.15.02	8	9	17	-1	-
7.16.02	37	25	62	12	+
7.23.02	27	27	54	0	0
7.24.02	34	18	52	16	+
7.29.02	9	0	9	9	+
7.30.02	0	1	1	-1	-
n	9	9	9	9	8
Total	145	105	250	40	
Mean	16.1	11.7	27.8	4.4	
Percent	58%	42%	100%		
No. +					5
Significant?					No

	30W	30E			
Date	**Plate**	**No Plate**	**Total**	**Diff.**	**Sign**
6.18.02	32	26	58	6	+
7.03.02	19	9	28	10	+
7.04.02	12	2	14	10	+
7.09.02	6	3	9	3	+
7.10.02	27	15	42	12	+
7.15.02	11	7	18	4	+
7.16.02	14	12	26	2	+
7.23.02	47	28	75	19	+
7.24.02	26	33	59	-7	-
7.29.02	7	2	9	5	+
7.30.02	2	0	2	2	+
n	11	11	11	11	11
Total	203	137	340	66	
Mean	18.5	12.5	30.9	6.0	
Percent	60%	40%	100%		
No. +					10
Significant?					Yes

alpha = .05

M = data missing

Down Counts at Weirs 27 and 29 with a Steel Plate (Plate) Upstream of One Orifice and Diffuser Gratings (No plate) Upstream of the Other Orifice

	27E	27W			
Date	**Plate**	**No Plate**	**Total**	**Diff.**	**Sign**
6.18.02	0	1	1	-1	-
7.03.02	M	M	M	M	M
7.04.02	0	0	0	0	0
7.09.02	0	2	2	-2	-
7.10.02	2	4	6	-2	-
7.16.02	0	1	1	-1	-
7.22.02	M	M	M	M	M
7.23.02	2	3	5	-1	-
7.24.02	0	0	0	0	0
7.29.02	0	0	0	0	0
7.30.02	0	0	0	0	0
n	9	9	9	9	5
Total	4	11	15	-7	
Mean	0.4	1.2	1.7	-0.8	
Percent	27%	73%	100%		
No. -					5
Significant?					No

	29W	29E			
Date	**Plate**	**No Plate**	**Total**	**Diff.**	**Sign**
6.18.02	28	6	34	22	+
7.03.02	0	1	1	-1	-
7.04.02	0	4	4	-4	-
7.09.02	0	8	8	-8	-
7.10.02	0	14	14	-14	-
7.16.02	0	0	0	0	0
7.22.02	0	0	0	0	0
7.23.02	4	0	4	4	+
7.24.02	0	0	0	0	0
7.29.02	0	1	1	-1	-
7.30.02	0	0	0	0	0
n	11	11	11	11	7
Total	32	34	66	-2	
Mean	2.9	3.1	6.0	-0.2	
Percent	48%	52%	100%		
No. -					5
Significant?					No

M = data missing

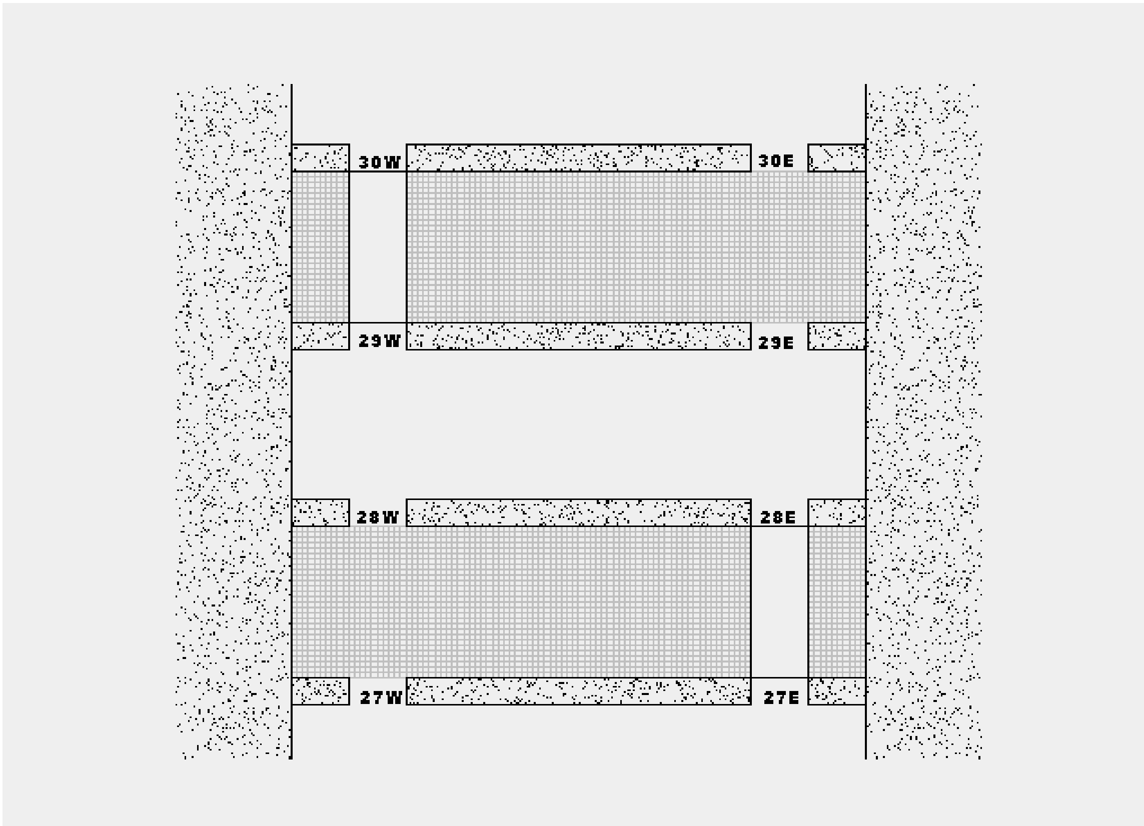
Up Counts at Weirs 27 and 29 with No Steel Plates or Diffuser Gratings

Downstream of the Orifices

Date	27E	27W	Total	Diff.	Sign
6.18.02	12	23	35	-11	-
7.04.02	2	1	3	1	+
7.09.02	2	8	10	-6	-
7.10.02	25	21	46	4	+
7.16.02	30	18	48	12	+
7.23.02	21	30	51	-9	-
7.24.02	19	12	31	7	+
7.29.02	2	5	7	-3	-
7.30.02	0	0	0	0	0
n	9	9	9	9	8
Total	113	118	231	-5	
Mean	12.6	13.1	25.7	-0.6	
Percent	49%	51%	100%		
No. +					4
Significant?					No

Date	29E	29W	Total	Diff.	Sign
6.18.02	16	158	174	-142	-
7.03.02	7	11	18	-4	-
7.04.02	14	2	16	12	+
7.09.02	24	8	32	16	+
7.10.02	45	12	57	33	+
7.16.02	35	32	67	3	+
7.22.02	16	25	41	-9	-
7.23.02	36	41	77	-5	-
7.24.02	21	23	44	-2	-
7.29.02	3	1	4	2	+
7.30.02	0	1	1	-1	-
n	11	11	11	11	11
Total	217	314	531	-97	
Mean	19.7	28.5	48.3	-8.8	
Percent	41%	59%	100%		
No. +					5
Significant?					No

M = data missing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